Remarks on the Reverse Auction

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Comments based largely on "Design of the FCC Incentive Auctions", Yeon-Koo Che, Phil Haile, MK on behalf of AT&T

(thanks also to Lili Dworkin)

Sources of Complexity in the Reverse

- Bidding and Strategic
  - simple bidding rules
  - strategic simplicity
  - relatively transparent outcomes
- Interaction and Coordination with Forward
  - clearing targets and closing conditions
  - sequential vs. interleaved
- Computational and Algorithmic
  - selection of winners subject to feasible repacking of losers
  - worst-case intractability of all forms of repacking
  - must exploit “special structure” of repacking constraint network, valuations
- No Avoiding Complexity!

Possible Reverse Mechanisms

- VCG
  - truthfulness dominant strategy
  - hard to understand
  - most computationally difficult (multiple ILPs vs. feasibility checks)
  - may be an important benchmark
- Other Sealed Bid (e.g. Pay-as-Bid)
  - strategically complex
  - hard to analyze
- Descending Clock (MALS)
  - truthfulness weakly dominant strategy
  - relatively easy to understand
  - computationally challenging

Proposal: Single-Pass Descending Clock

- Run a single reverse with decreasing clearing targets (max to min)
- When a clearing target is reached, record winners and prices
- Continue clocks until final clearing target
- Forward: run using highest clearing target and reverse prices
- If closing conditions met, terminate; else continue with lower target
- Advantages:
  - no change in reverse incentives or strategy
  - no need to reconvene multiple reverse auctions
  - reverse bids determined at one time, no valuation leakage over time
  - simplifies a two-sided closing trial
- Potential disadvantages:
  - broadcasters may reveal more information
- Single-pass with proxy bidding
  - proxy takes reservation value, bids accordingly
  - main advantage: offline computations!

Algorithmic Challenges in the Reverse

- Regardless of mechanism, encounter repacking under interference
- Interference constraints are physical and complex
- Geographically regional, but propagate nationally ("daisy chain")
- Both co-channel and adjacent-channel constraints
- Many variants of the problem:
  - given repacking network and bids, find VCG winners and payments (ILP optimizations)
  - given same, find expenditure-minimizing winner set subject to repacking (other sealed)
  - given a proposed winner set, determine if losers can be feasibly repacked (clock)
- In the worst case, all are intractable and inapproximable!
- Main hopes:
  - customized algorithms tuned to the "special structure" of repacking constraints and broadcaster valuation models (need both inputs!)
  - empirical understanding of likely performance based on large-scale simulations
  - offline computation and precomputation

The Two Inputs

- Repacking Interference Constraints:
  - based on physical proximity of transmission towers, height, power, terrain,…
  - agnostic to DMAs, EAs, etc.
  - complex, but in principle can know in great detail
- Broadcaster Valuations:
  - may vary widely across broadcasters
  - may depend on broadcaster types, location, repacking difficulty,…
  - complex, and in principle cannot know in detail… but could consider plausible models
- In any reverse mechanism, interference and valuations will interact
  - e.g. in descending clock with truthful bidding, valuations determine order of exit
  - order of exit and interference network position determine complexity of repacking
- What do/could we know/model about these two inputs?
  - special structure of interference network
  - models of relationship of network position, geography or type to valuations
  - both could lead to specialized algorithms, simulations, assessment of difficulty, etc.

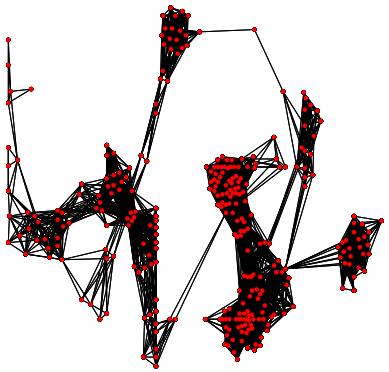
Structure of the Interference Network: Some Preliminary Analysis

Data Methodology

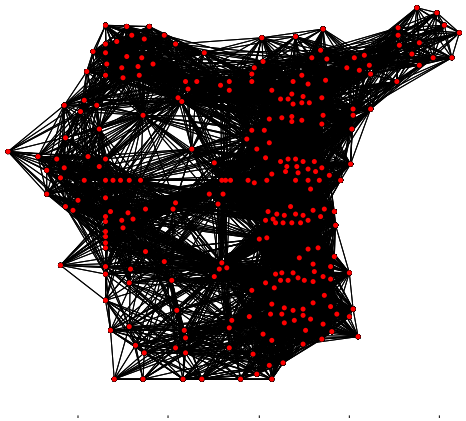
- Broadcaster dataset derived from FCC's CDBS and TV Query DBs (1/13)
  - records linked using Facility ID and Radio Service codes for full power (DT) and Class A stations (DC, CA) in UHF band
  - where multiple Facility IDs existed, selected location with highest power transmitter
  - because antenna height above average terrain (HAAT) is not provided for Class A stations, used antenna centerline above ground level (RCAGL)
- Interference Calculations
  - for co-channel interference, compared transmitter spacing to ensure interference contour did not intersect protected contour
  - for protected contour, used 41 dBu contour
  - for interference contour, used 15 dB D/U ratio (26 dBu contour) per 73.616(e)(1)(i)
  - contour distances estimated using FCC website calculator (computes F(50,90) only for UHF DTV)
  - for adjacent channel interference, used 73.623 requirements
  - transmitter spacing must be < 24 km or > 110 km

Connected Components

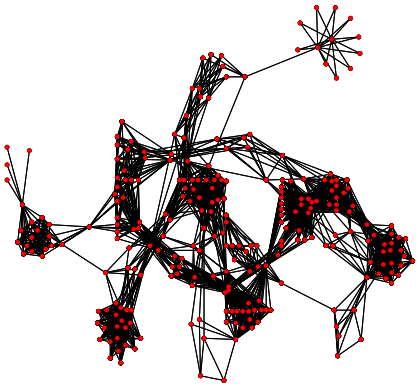
West Coast

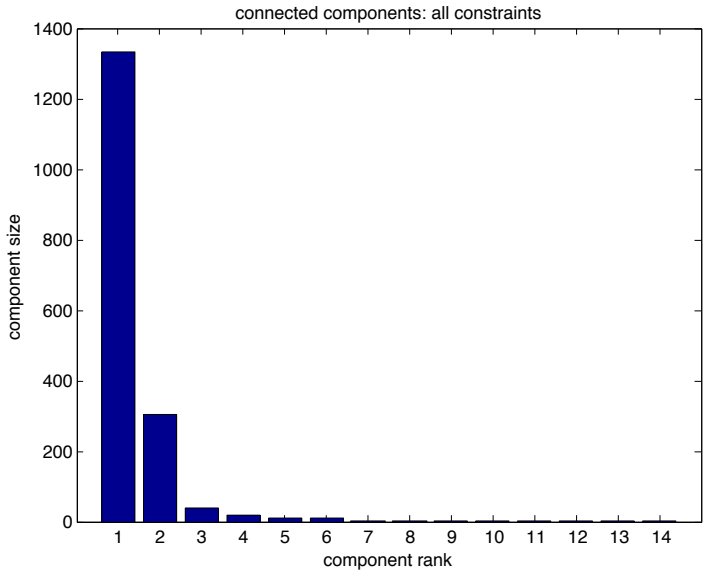


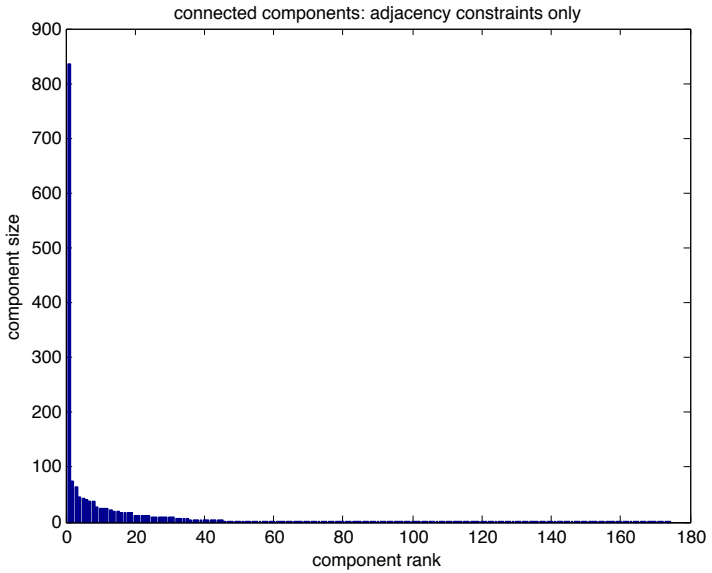
Within 5 degrees of NYC



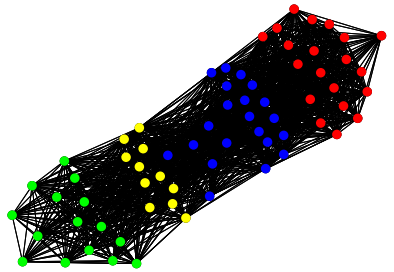
Within 5 degrees of NYC, adjacency constraints only



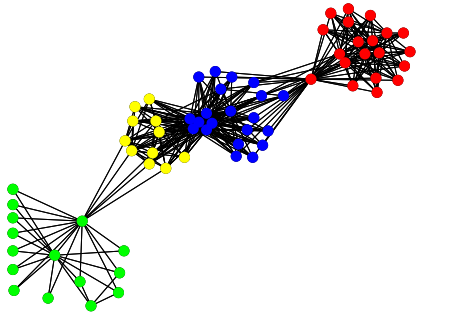




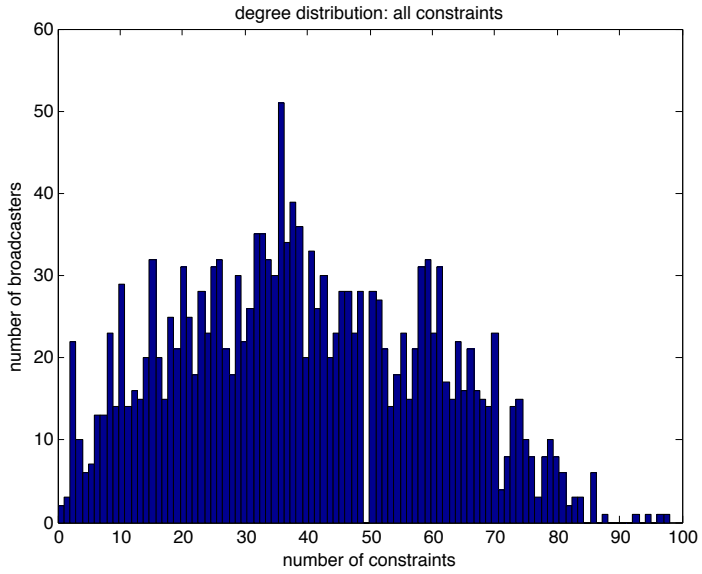
Philadelphia–New York–Hartford–Boston: all interference constraints

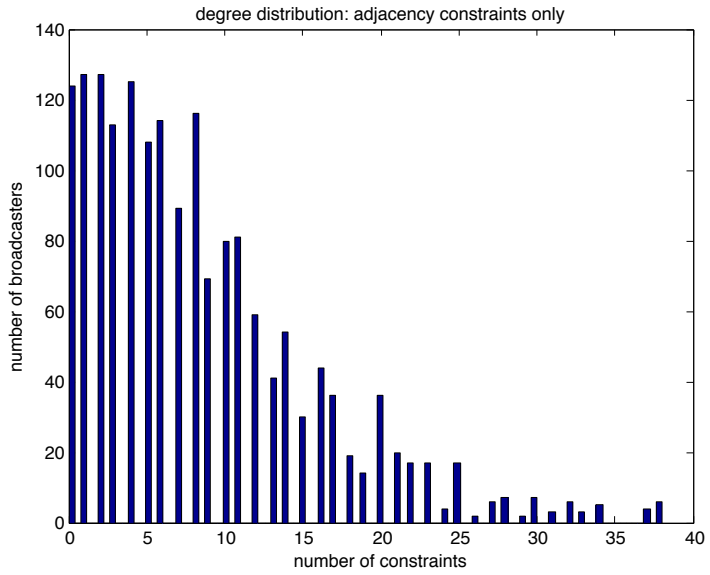


Philadelphia–New York–Hartford–Boston: adjacent channel constraints only



Degree Distributions and Clustering





- Correlations with degree:
  - power: 0.19
  - height: 0.38
  - population: 0.29
  - Northeast: 0.39
- Clustering:
  - N=1732, 34,201 edges
  - background density: 0.023
  - clustering coefficient: 0.73
- Strong locality, but very dense
- Factor via cutsets?

Models of Valuations

- What are the right/reasonable correlates of valuation?
- How are they related to repacking difficulty?
- Network Position
  - degree, centrality, betweenness…
  - most directly related to repacking complexity
- Geography
  - DMAs, EAs, Northeast corridor
- Broadcaster Types
  - commercial, non-profit, educational…

Auction Simulations

- Small-scale (single DMAs, 2 adjacent DMAs)
- Full-auction simulations (dynamics, winners, prices, etc.)
  - descending clock (and “myopic” repacking variant)
  - VCG
  - sealed pay-as-bid at full-info Nash
  - varying clearing target, number of repacking channels, valuations
  - subtlety for clock: feasibility of repacking *subject to clearing targets?*
- Permits comparison of solutions, prices, etc.
- Sample timings, CPU minutes
  - VCG: ~151 (single call to Matlab ILP ~22)
  - descending clock: ~0.7 (~n^2 calls to Minisat solver)
  - “myopic” clock: ~0.01